

# *Future Role of Nuclear Energy*

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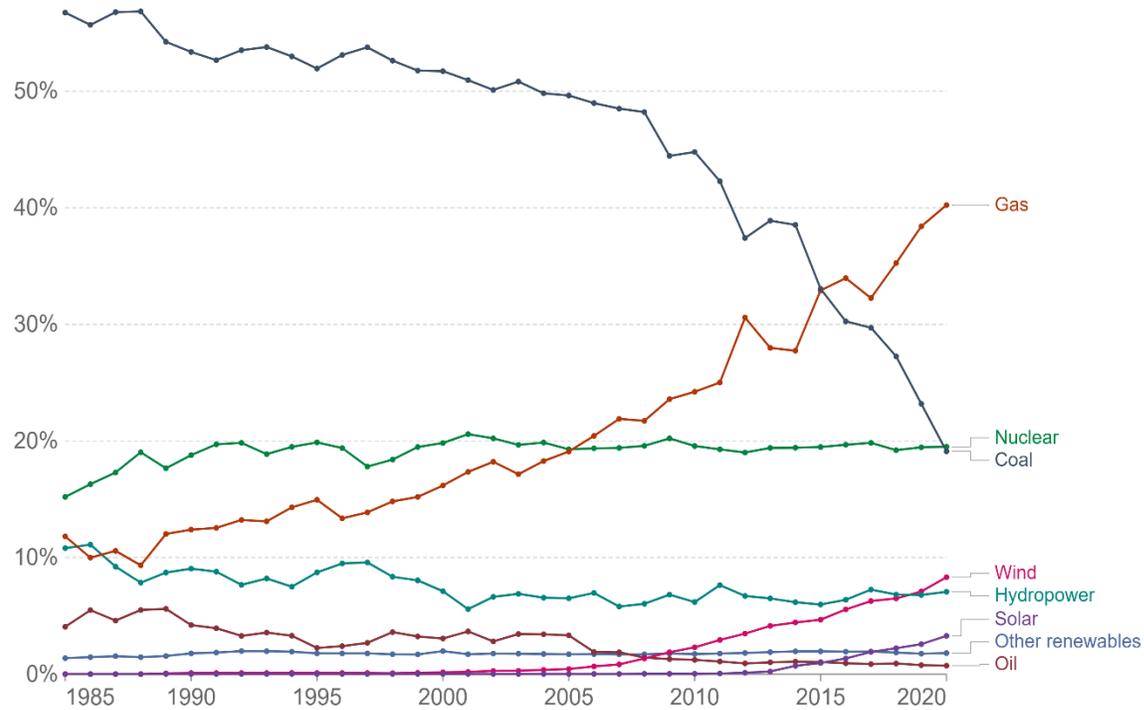




# What has really changed for electricity?

Share of electricity production by source, United States

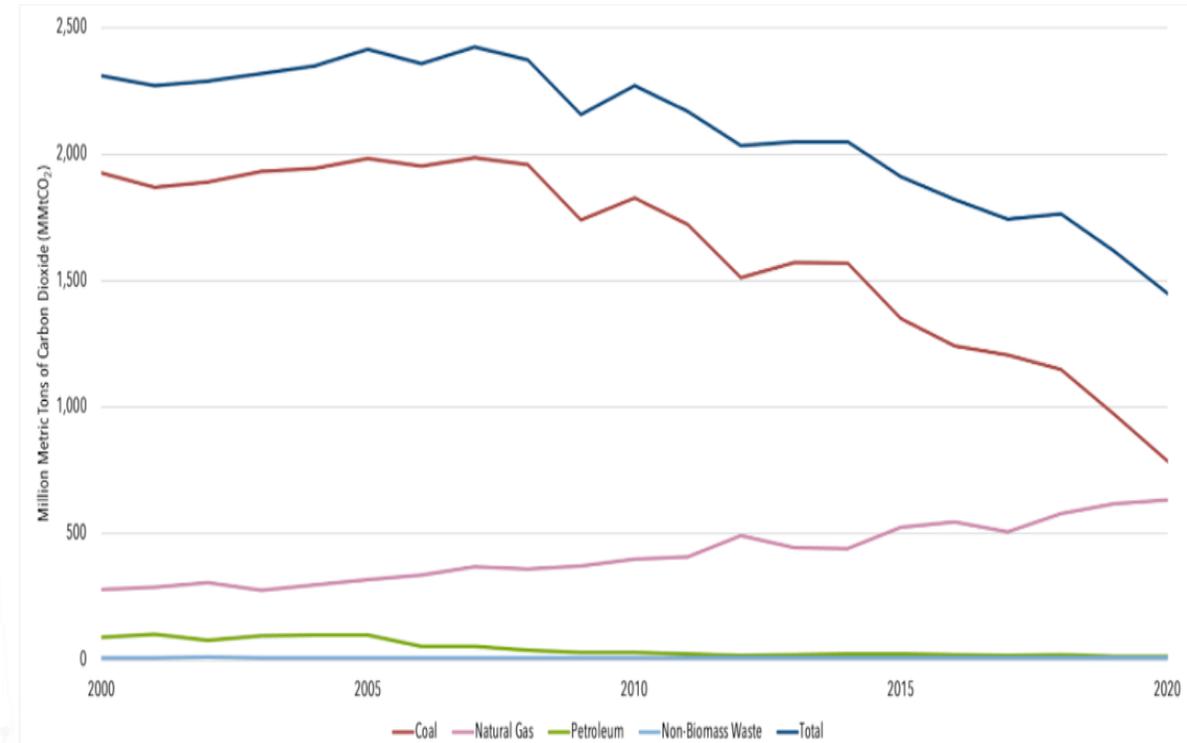
Our World in Data



Source: Our World in Data based on BP Statistical Review of World Energy & Ember

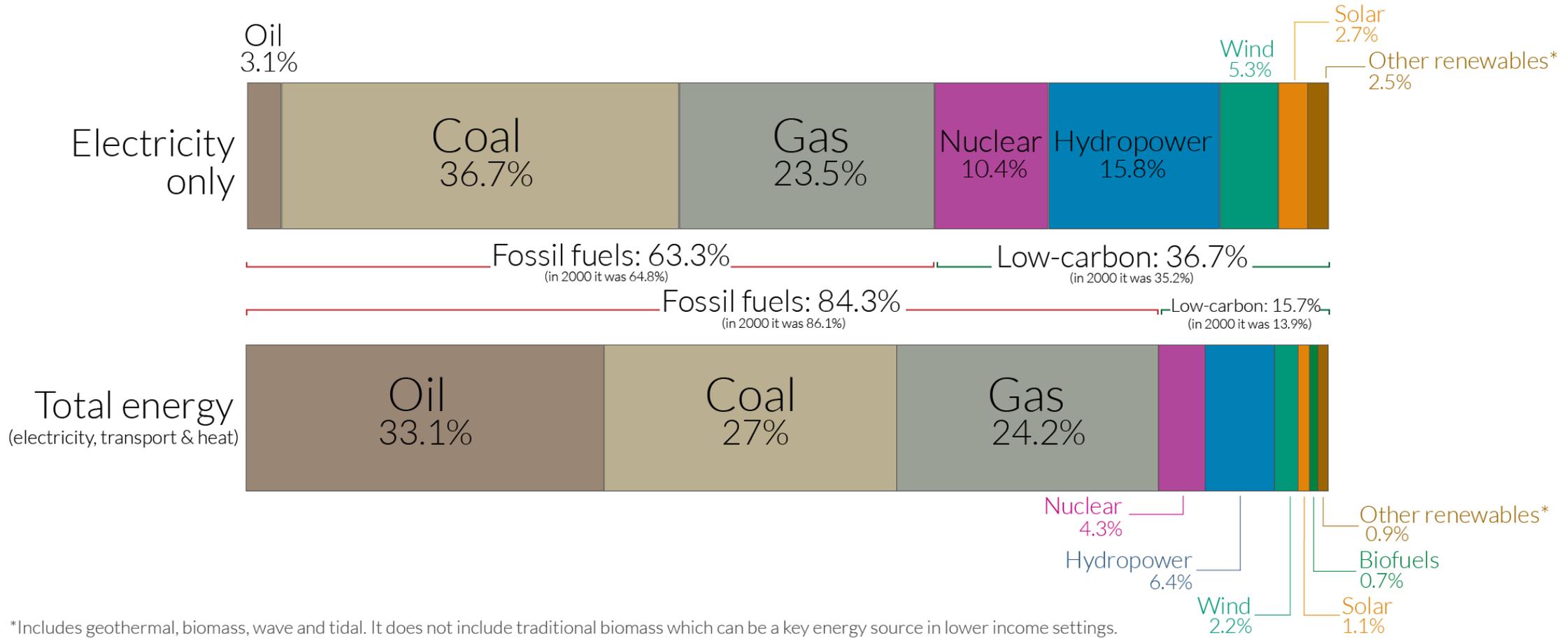
OurWorldInData.org/energy • CC BY

Trends in CO2 Emissions in the U.S. Power Sector, 2000–2020



Source: Monthly Energy Review EIA 2021

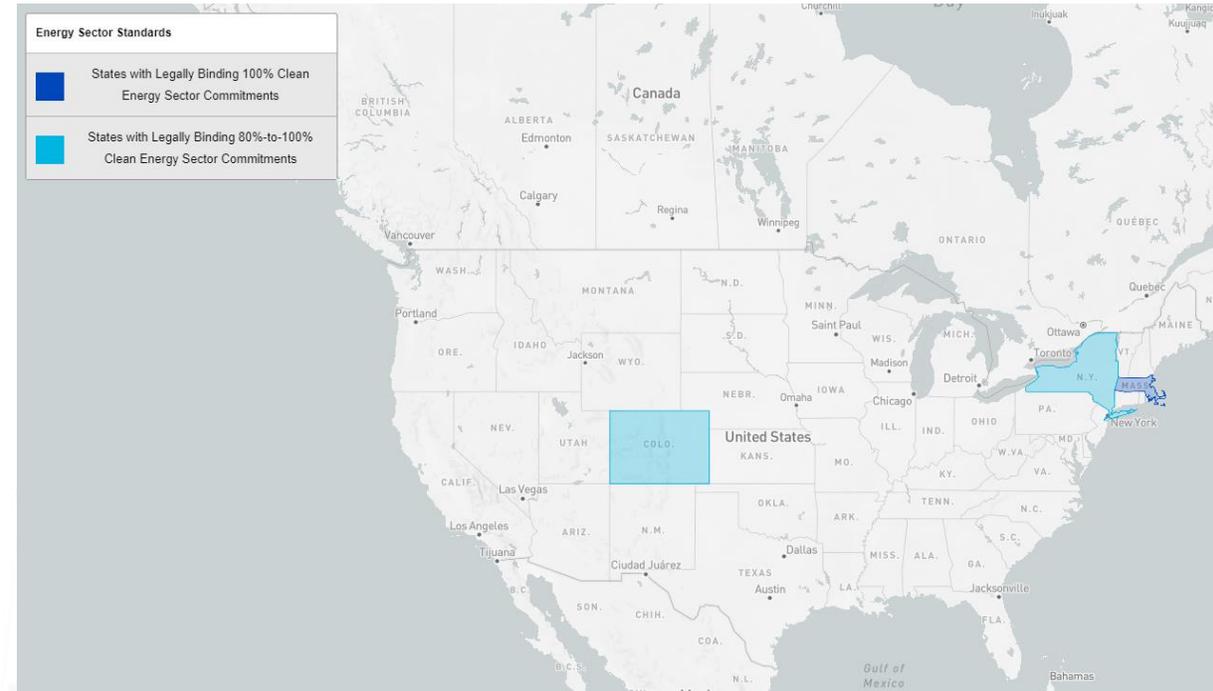
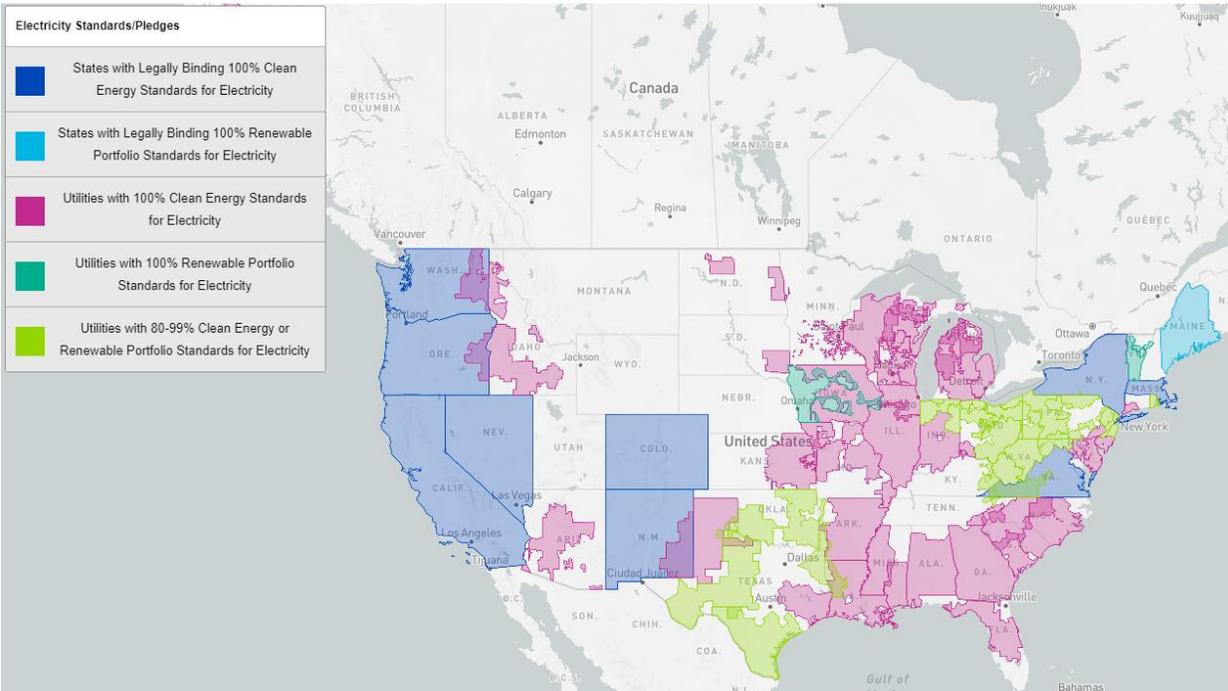
# More than one-third of global electricity comes from low-carbon sources; but a lot less of total energy does



\*Includes geothermal, biomass, wave and tidal. It does not include traditional biomass which can be a key energy source in lower income settings.



# US Decarbonization Targets – Electricity vs Energy; Utilities vs States



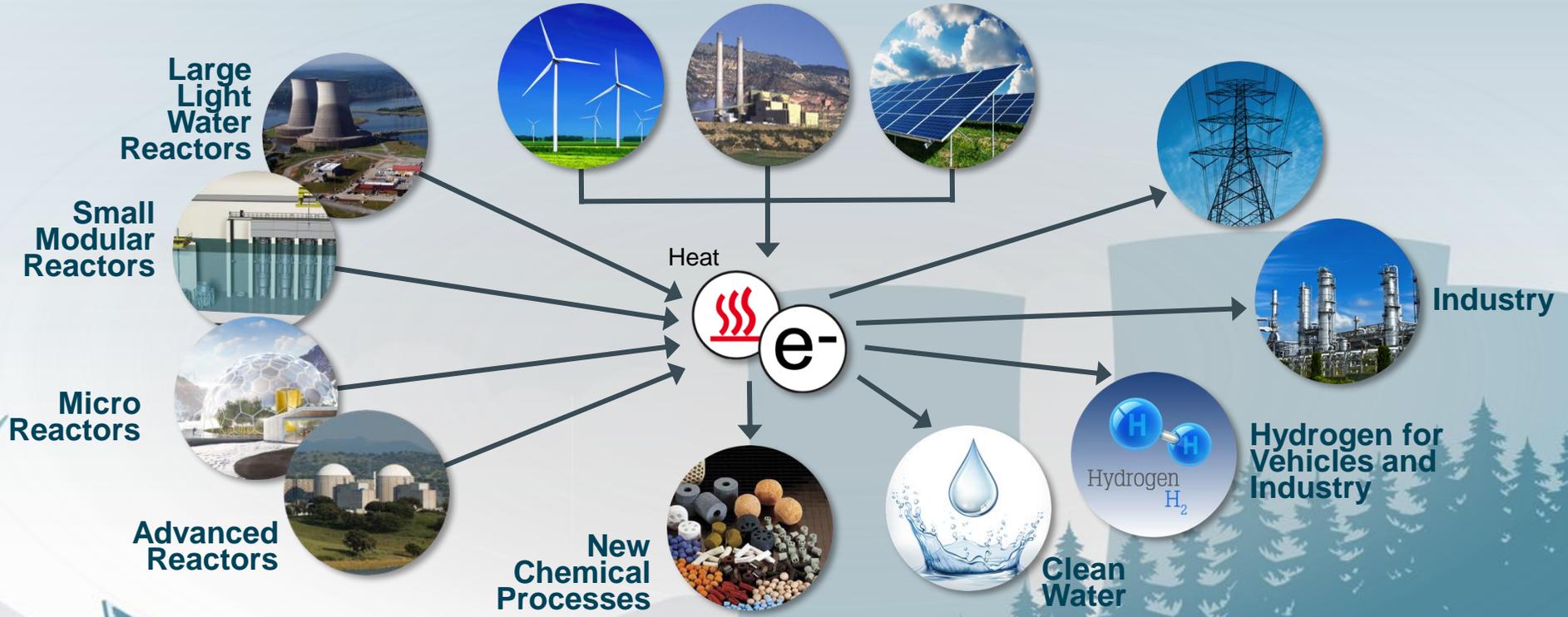


# IES

Integrated Energy Systems

## Future clean energy systems would leverage contributions from low emission energy generation for electricity, industry, and transportation

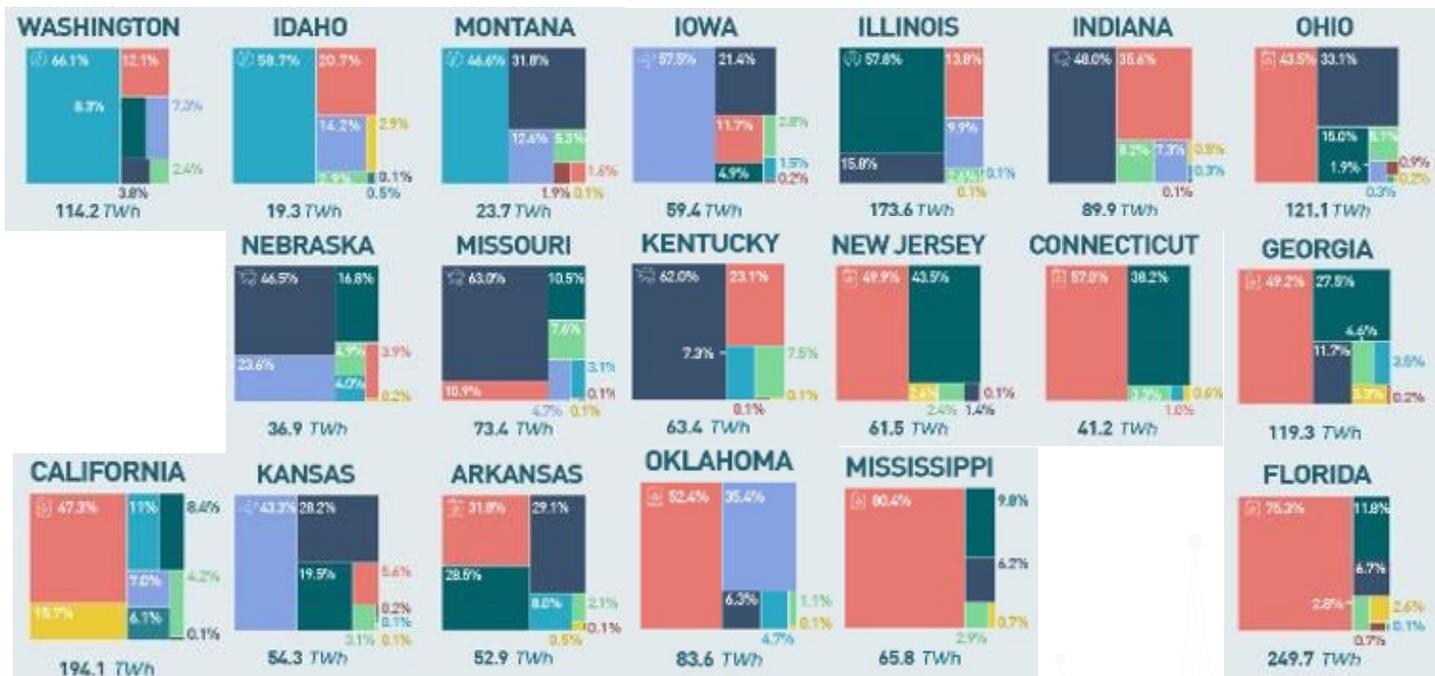
**Today**  
Electricity-only focus



A net zero future will take decades to achieve, will make us rethink energy across all sectors and gives us the opportunity to make the most of our resources!

# U.S. ELECTRICITY MIX

ELECTRICITY GENERATION BY STATE (2020)



Rapid decarbonization of the U.S. economy will require a diverse set of existing and new clean energy technologies.

## Emerging Technologies

- Carbon Capture
- Zero-Carbon Electricity Generation
- Energy Storage
- Zero-Carbon Fuels
- Vehicles
  - Electric vehicles
  - Zero-emission trucks
  - Engines capable of running on ammonia and for other transportation modes that are difficult to electrify
- Aviation
  - Advanced (more efficient) aviation technology
- Industrial Materials
  - Hydrogen-direct reduced Iron

# Deployment Constraints May Determine Future Energy Mix

Primary Energy Source	Key Deployment Challenges	2050 Build-out Across the Range of Modeling Scenarios
Renewables	Resource availability, siting, social license, and transmission requirements	1,700 – 5,500 gigawatts
Nuclear	Commercial status of new technology, ability to rapidly scale deployment in light of siting challenges and complex regulatory requirements, socio-political acceptance, and need for resolution of waste disposal issue	11 – 113 gigawatts
Gas	Need to limit methane emissions from extraction, address local environmental impact, social license, infrastructure and other constraints on CO2 injection rate for geologic sequestration	0 – 30 trillion cubic feet
Biomass	Limits on feedstock types and volumes that can be considered carbon-neutral	350 – 700 million metric dry tons

# Infrastructure Needs for 2050

Continue cost reductions for low carbon technologies  
 Preserve infrastructure where we can

- Double

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- Double

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- 10X- 30X

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- 8X capacity today

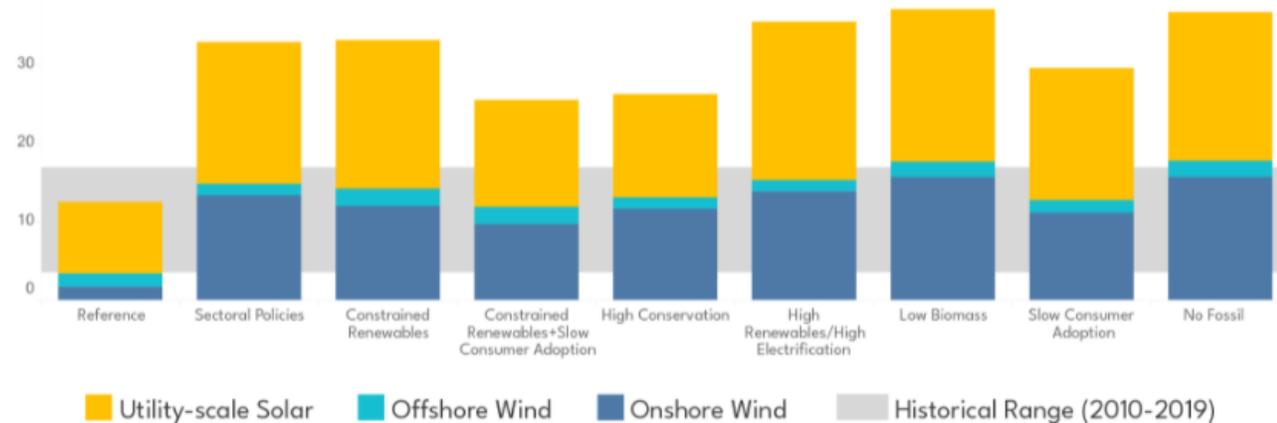
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- Replace 10B gal Diesel

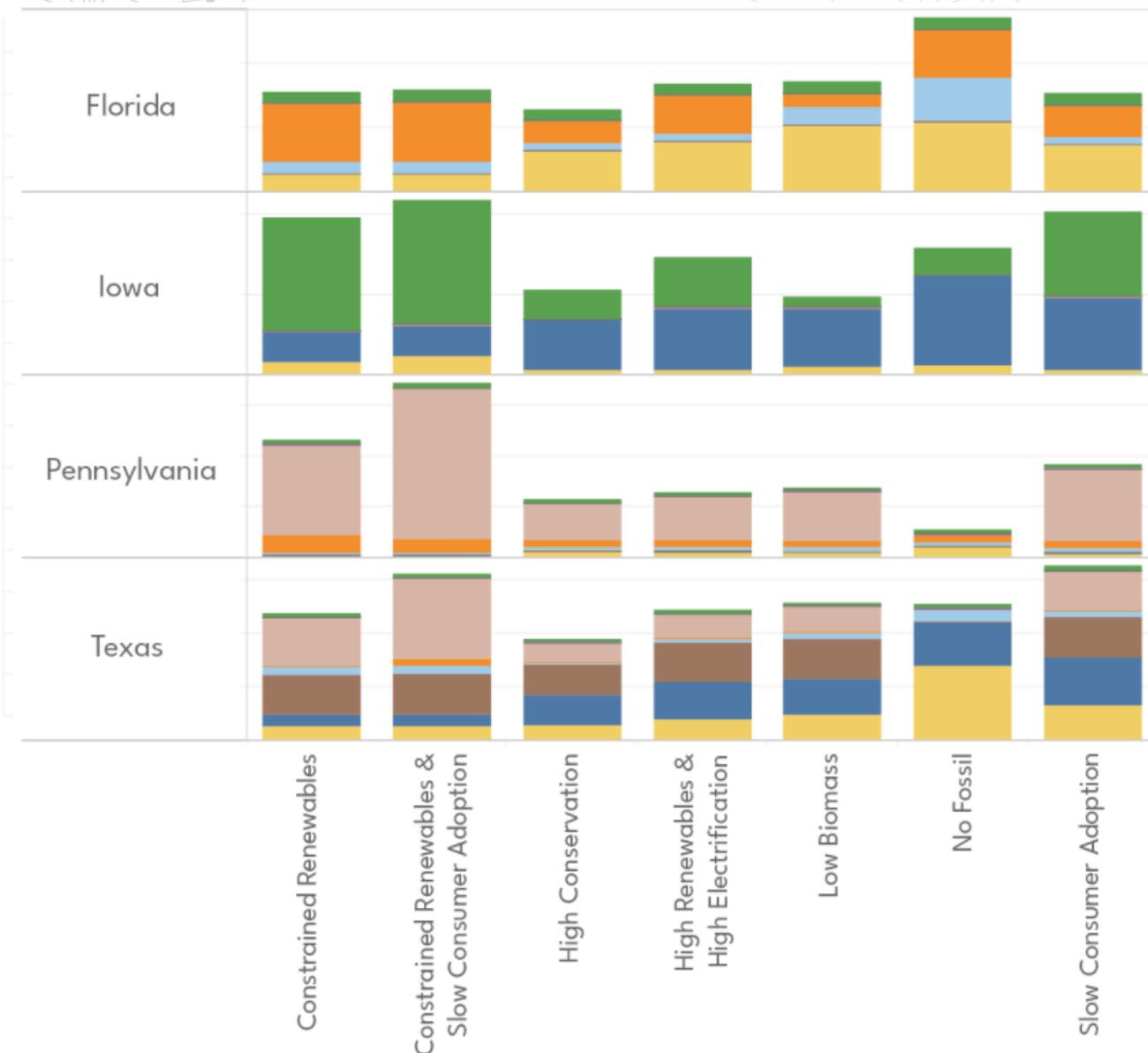
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- Build at least 102 gigawatts (GW) of wind
- Build at least 174 GW of solar
- Manufacture and sell 15 million to 45 million zero-emission vehicles
- Capture over 212 million metric tons (MMT) and sequester more than 165 MMT of CO2 annually by 2030
- Produce over 1.4 quads of zero-carbon fuels annually by 2030

Average Annual Build: 2021-2030  
 GW per year



# Primary Energy in 2050 – US and 4 States

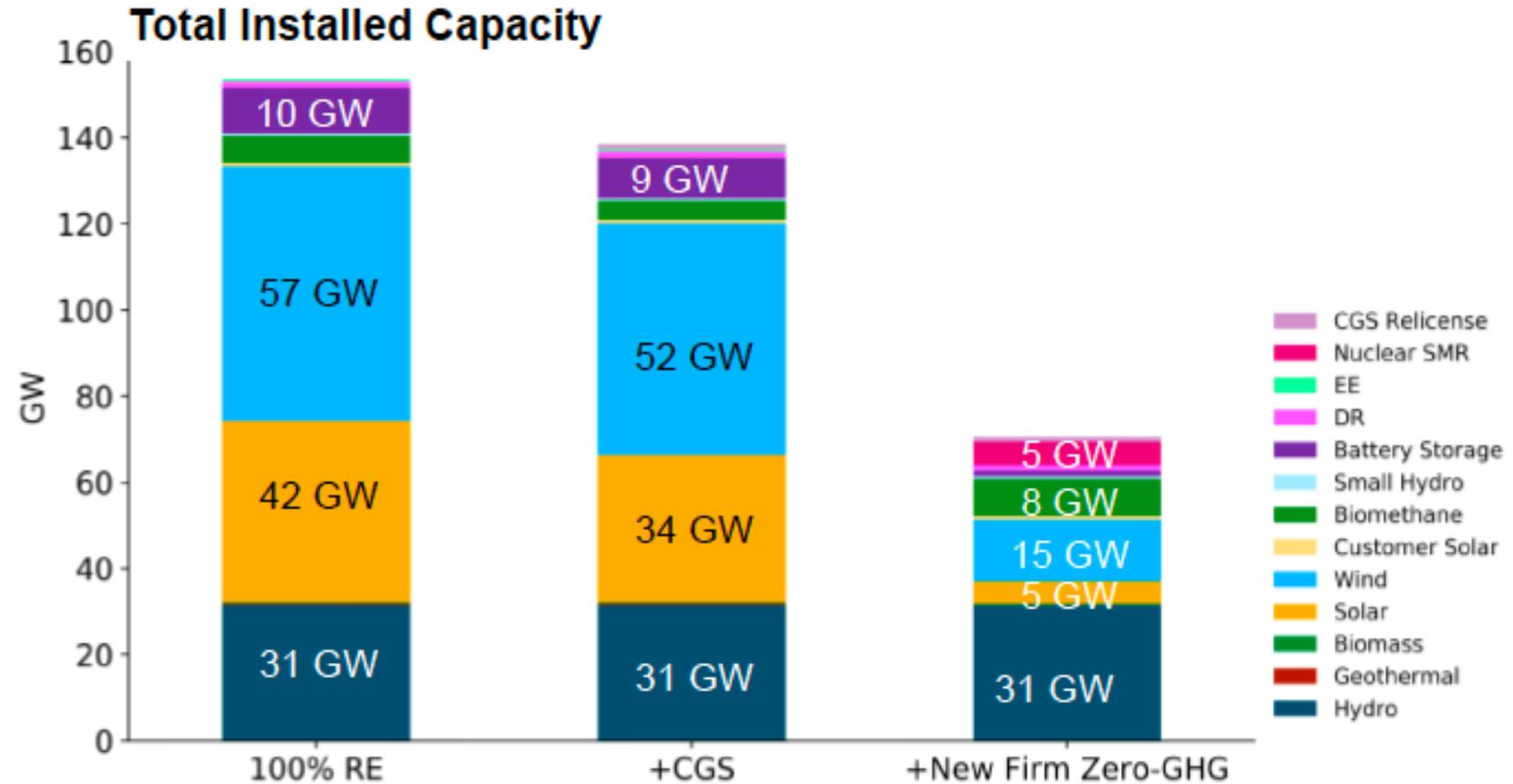


Inclusive policies for technology innovation and deployment will allow all regions of the U.S. to leverage their different resource endowments and develop new clean energy industries.

# Meeting Emissions Goals with Nuclear Leads to Local Resource Optimization

- E3 study for Energy Northwest on achieving 100% carbon free by 2045:
  - Firm zero-emitting resources like nuclear reduce costs up to \$8B per year
  - Adding 6.5GW firm avoids 91GW non-firm
- Other studies have been shared publicly

NOTE: CGS – Columbia Generating Station

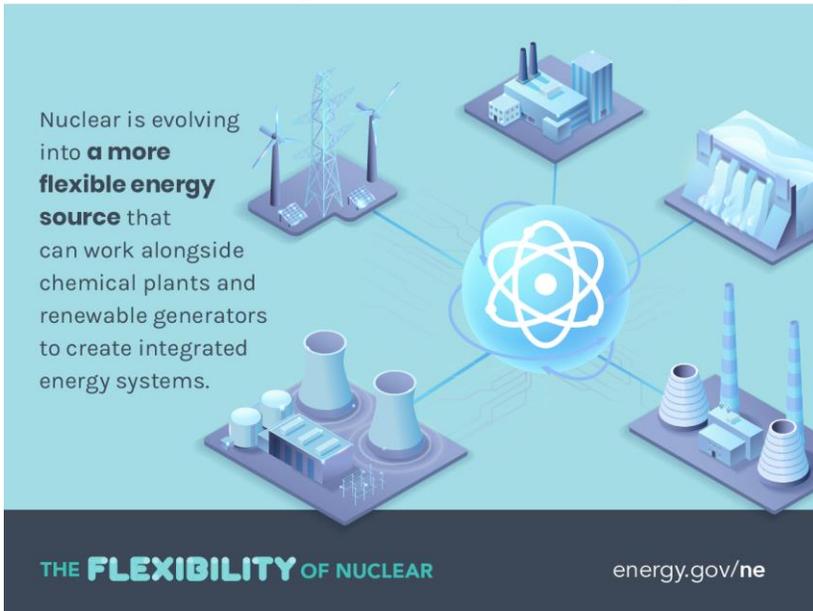


Pacific Northwest Zero-Emitting Resources Study, Energy and Environmental Economics, Inc.

<https://www.ethree.com/wp-content/uploads/2020/02/E3-Pacific-Northwest-Zero-Emitting-Resources-Study-Jan-2020.pdf>

# New operational paradigms—nuclear energy flexibility

Nuclear is evolving into **a more flexible energy source** that can work alongside chemical plants and renewable generators to create integrated energy systems.

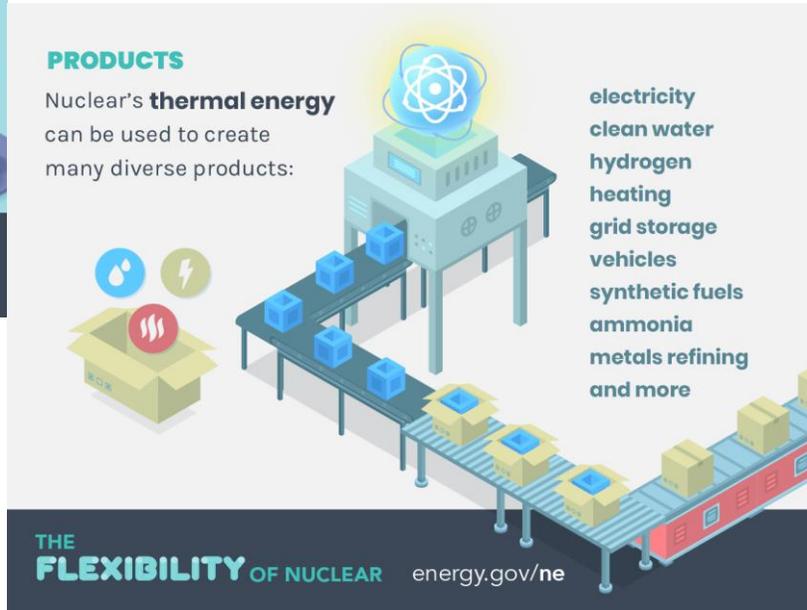


**THE FLEXIBILITY OF NUCLEAR** energy.gov/ne

**Nuclear flexibility can be key in enabling other clean energy generators.**

**PRODUCTS**  
Nuclear's **thermal energy** can be used to create many diverse products:

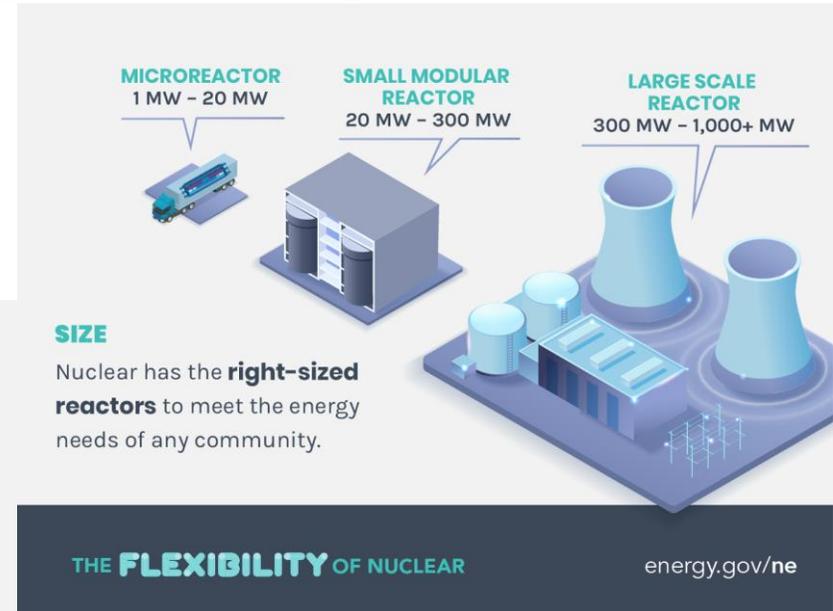
- electricity
- clean water
- hydrogen
- heating
- grid storage
- vehicles
- synthetic fuels
- ammonia
- metals refining
- and more



**THE FLEXIBILITY OF NUCLEAR** energy.gov/ne

**SIZE**  
Nuclear has the **right-sized reactors** to meet the energy needs of any community.

- MICROREACTOR**  
1 MW - 20 MW
- SMALL MODULAR REACTOR**  
20 MW - 300 MW
- LARGE SCALE REACTOR**  
300 MW - 1,000+ MW



**THE FLEXIBILITY OF NUCLEAR** energy.gov/ne

- **Operational flexibility**
  - **Product flexibility**
    - **Deployment flexibility**

# Advanced Fission

- Categorized in terms of capacity
  - Microreactors: <20 MWe (megawatt electric)
  - Small reactors: 20 MWe – <300MWe
    - Small Modular Reactors: use modular construction
  - Medium reactors: 300MWe - 700 MWe
  - Large reactors: > 700 MWe
- Variety of coolants (gas, sodium, salt, lead, water)
- Clean, high availability
- Diverse markets
- Improved safety, waste, security, and target economics
- 60+ private sector projects

**Small Town: 1 Megawatt (MW)**

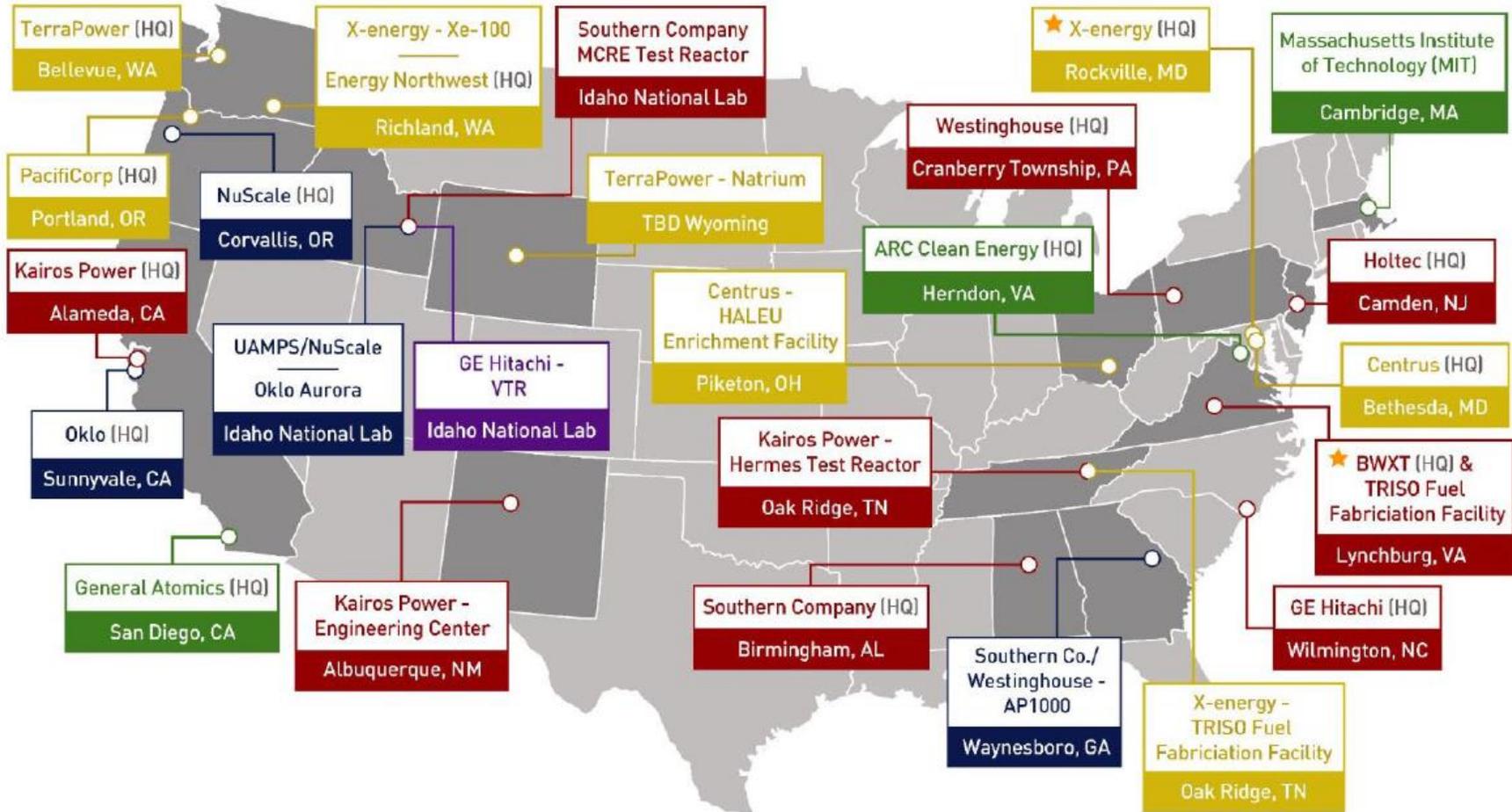
**Mid-size City: 1 Gigawatt (GW)**

**The US: 1,000 Gigawatts**



Image courtesy of GAIN and Third Way, inspired by the *Nuclear Energy Reimagined* concept led by INL. Learn more about these and other energy park concepts at [thirdway.org/blog/nuclear-reimagined](https://thirdway.org/blog/nuclear-reimagined)





**ARDP Demonstration**  
[Advanced Reactor Demonstration Program]

**ARDP Risk Reduction**  
[Advanced Reactor Demonstration Program]

**ARC-20**  
[Advanced Reactor Concepts-20]

**Commercial Reactors**

**Versatile Test Reactor (VTR)**

**★ Department of Defense Project Pele Awards**

# CLEARPATH

## Public-Private Partnerships (Related to Advanced Nuclear over past 5 years)

Name	#	Size, Length	Cost Share	Federal (\$M)	Private (\$M)	Total (\$M)
NE Voucher (GAIN)	60	<\$500K, 1 year	80/20	19	5	24
Industry Funding Opportunity Announcement (FOA) -1817						
First of a Kind	6	\$10-40M, 3 year	50/50	70	72	142
Adv Rx Dev	23	\$500K – 20M, 2 year	80/20	89	38	127
Reg Assist	9	\$50 – 500K, 1 year	80/20	4.2	1.5	5.7
Advanced Reactor Demonstration Program						
Demo	2	\$160M, within 5-7 years	50/50	2,620	2,620	5,240
Risk Reduction	5	\$30M, within 10-14 years	80/20	602	403	1,005
Adv Rx Con	3	\$20M, demo in mid 2030s	80/20	56	14	70
				3,460	3,153	6,614

**2016 \$2M**

**2017 \$4M**

**2018 \$157M**

**2019 \$87M**

**2020+ \$6.4B**

# Advanced Nuclear Industry Milestones in New Website



## TerraPower announces SMR proj...

DATE

6/2/2021

DESCRIPTION

Wyoming Governor Mark Gordon announced that TerraPower and PacifiCorp will be working together to demonstrate TerraPower's Sodium small modular react...

WEB RESOURCES

TerraPower, Wyoming Governor and PacifiCo



## Montana relaxes nuclear constru...

DATE

4/30/2021

DESCRIPTION

Signed by Governor Greg Gianforte in Spring of 2021, HB 273 grants the Montana State Legislature with the authority to approve the construction of new nuclear ...

WEB RESOURCES

HB 273: Eliminate Restrictions on Nuclear Fa



## NJBPU extends nuclear ZECs for t...

DATE

4/27/2021

DESCRIPTION

In a unanimous vote, the New Jersey Board of Public Utilities (NJBPU) extended the ZEC credits for PSEG and Exelon's nuclear plants for an additional three years. PSEG owns t...

WEB RESOURCES

New Jersey Regulators Extend Nuclear Subs



**MARVEL**

## MARVEL is approved

DATE

4/13/2021

DESCRIPTION

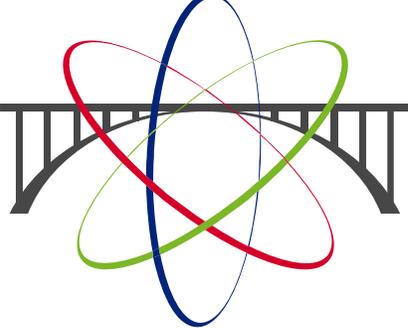
As part of the Department of Energy's (DOE) Microreactor Program, the Microreactor Applications and Research Validation and Evaluation (MARVEL) Project will be house...

WEB RESOURCES

INL's MARVEL could demonstrate remote op

The new website captures key industry achievements in technology, development, policy, regulation, finance, integrated systems.

<https://www.airtable.com/universe/expnrIMohdf6dlvZI/milestones-in-advanced-nuclear?explore=true>



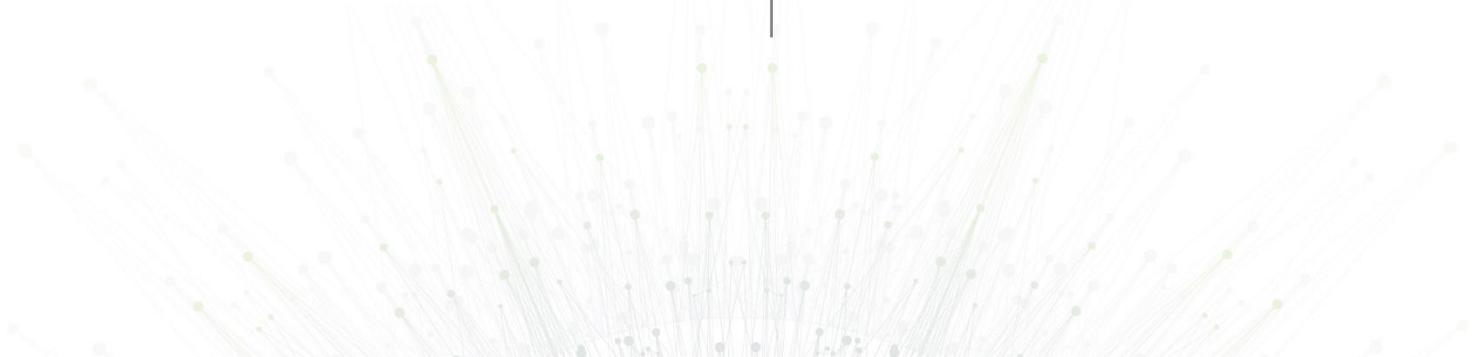
# **GAIN**

Gateway for Accelerated  
Innovation in Nuclear



@GAINnuclear

gain.inl.gov



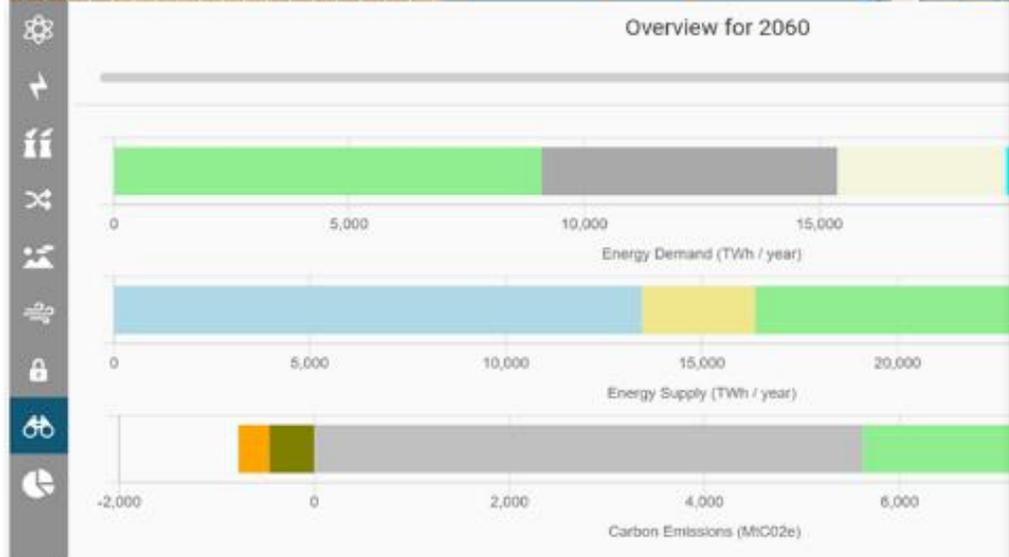
# GAIN Energy Calculator

The GAIN Energy Calculator is available at <https://gain.ornl.gov/#/>.

SELECTED: US **Total CO<sub>2</sub> Reduction (target: 100%)**



Overview for 2060



### DEMAND - BUSINESS (7)

**Growth in industry** A

US industry output grows by 1% every year.

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**Energy intensity of industry** A

No electrification of processes; little improvement in reducing energy intensity.

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**Commercial demand for heating and cooling** 1

Space heating demand, hot water demand, and cooling demand increased by 3% every 5 years.

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**Commercial heating electrification** A

The proportion of non-domestic heat supplied using electricity is 0-10%, as today.

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**Commercial heating that isn't electric** 1

The dominant non-electric heat source is gas or gas CHP (biogas if available).

### SUPPLY - ELECTRICITY GENERATION (14)

**Nuclear power stations** 1

No new nuclear energy.

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**CCS power stations** 1

Demonstration plants only; no roll-out of CCS.

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**CCS fuel mix** 1

Current fraction (38% Coal, 62% Natural gas).

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**Offshore wind** 1

No offshore wind.

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**Onshore wind** 1

Follow current regional trajectory.

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**Wave** JK

None in 2060.